US011036185B2

(12) **United States Patent**
Zaugg et al.

(10) **Patent No.: US 11,036,185 B2**
(45) **Date of Patent: Jun. 15, 2021**

(54) **TIMEPIECE MECHANISM FOR DISPLAYING THE LUNAR DAY AND MOON PHASE, WITH A CORRECTION SYSTEM USING A DOUBLE KINEMATIC CHAIN**

(71) Applicant: **Montres Breguet S.A.**, L'Abbaye (CH)

(72) Inventors: **Alain Zaugg**, Le Sentier (CH); **Christophe Riedo**, Le Lieu (CH)

(73) Assignee: **Montres Breguet S.A.**, L'Abbaye (CH)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 460 days.

(21) Appl. No.: **16/170,228**

(22) Filed: **Oct. 25, 2018**

(65) **Prior Publication Data**

US 2019/0146414 A1 May 16, 2019

(30) **Foreign Application Priority Data**

Nov. 10, 2017 (EP) 17201110

(51) **Int. Cl.**
G04B 19/26 (2006.01)

(52) **U.S. Cl.**
CPC ***G04B 19/268*** (2013.01)

(58) **Field of Classification Search**
CPC G04B 19/26; G04B 19/262; G04B 19/268
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,859,948 B2 * 12/2010 Plomb G04B 47/044 368/16
2014/0126336 A1 5/2014 Goeller et al.

FOREIGN PATENT DOCUMENTS

CH	697674	B1 *	1/2009		G04B 19/268
EP	0 566 529	A1	10/1993		
EP	2 687 918	A1	1/2014		
EP	2 728 420	A1	5/2014		
WO	WO 91/11756	A1	8/1991		
WO	WO-9111756	A1 *	8/1991		G04B 19/268

OTHER PUBLICATIONS

European Search Report dated May 24, 2018 in European Application 17201110.8 filed on Nov. 10, 2017 (with English Translation of Categories of Cited Documents).
Glaser, G. "Astronomische Indikationen Bei Uhren",Jahrbuch Der Deutschen Gesellschaft Fur Chronometrie, Deutschen Gesellschaft Fur Chronometrie E.V. Stuttgart, DE, vol. 40, ISSN: 0373-7616, 1989, pp. 24.

* cited by examiner

Primary Examiner — Edwin A. Leon
Assistant Examiner — Jason M Collins
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

Timepiece mechanism for displaying the lunar day and the moon phase. The moon is represented by a sphere mounted on a meridian wheel and includes a first rotating element meshed with a drive mechanism, a second rotating element friction mounted on the first rotating element, a moon wheel set coupling the first rotating element to the meridian wheel, a transmission wheel with a jumper spring, a system for correcting the lunar day display via a first correction wheel bypassing the transmission wheel and including the meridian wheel, a system for correcting the lunar day display via a second correction wheel including the transmission wheel.

15 Claims, 7 Drawing Sheets

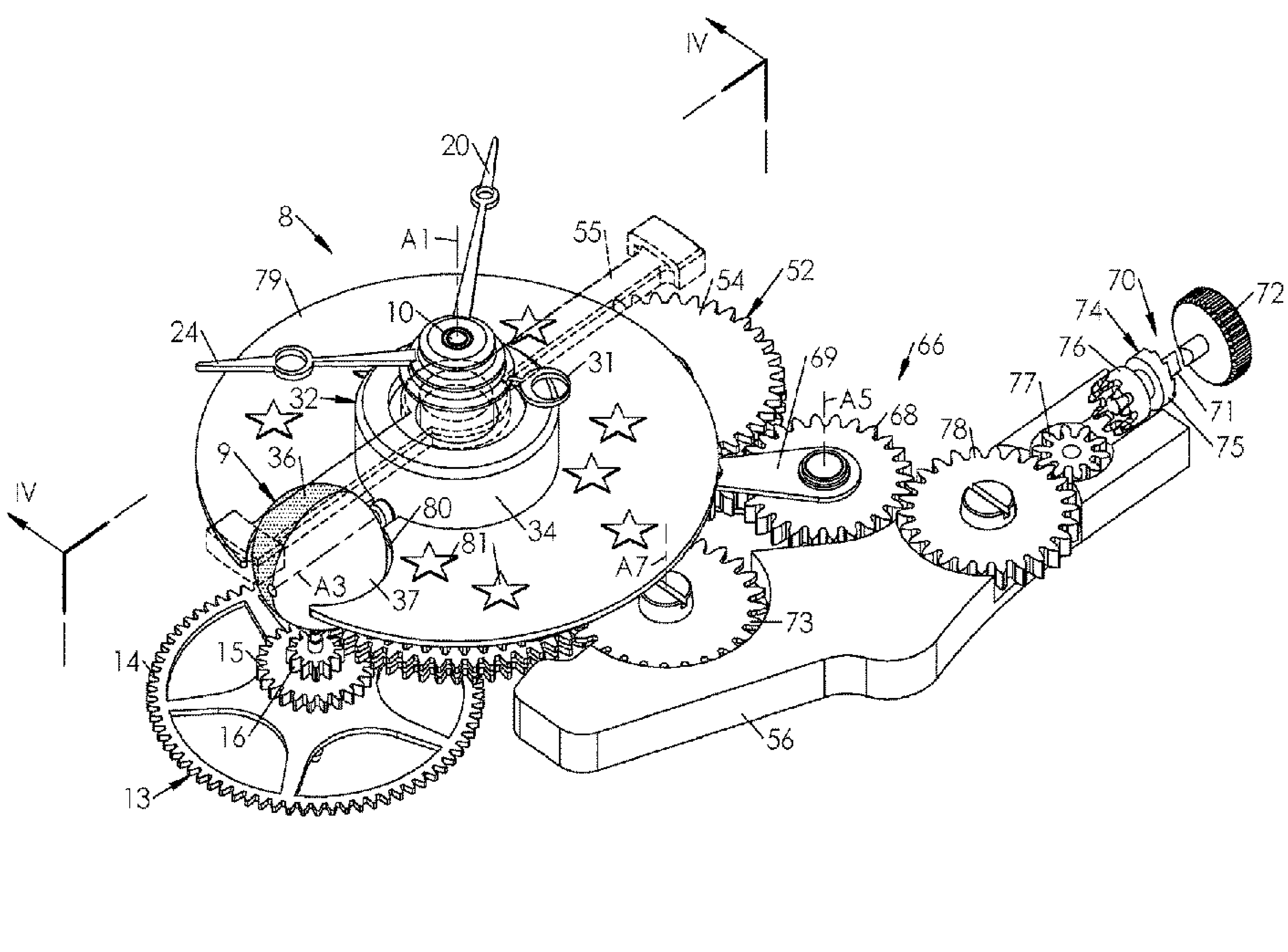
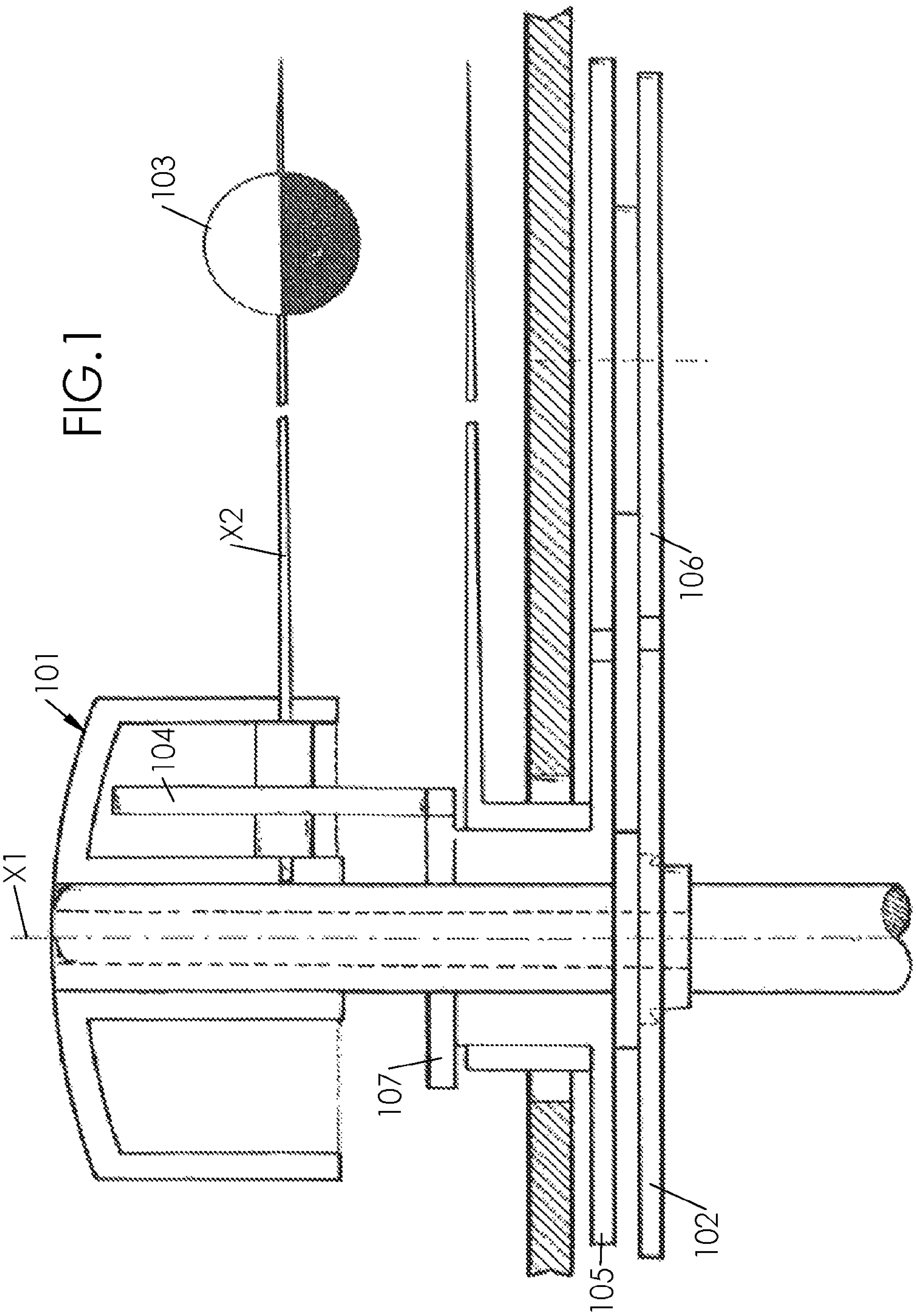


FIG.1



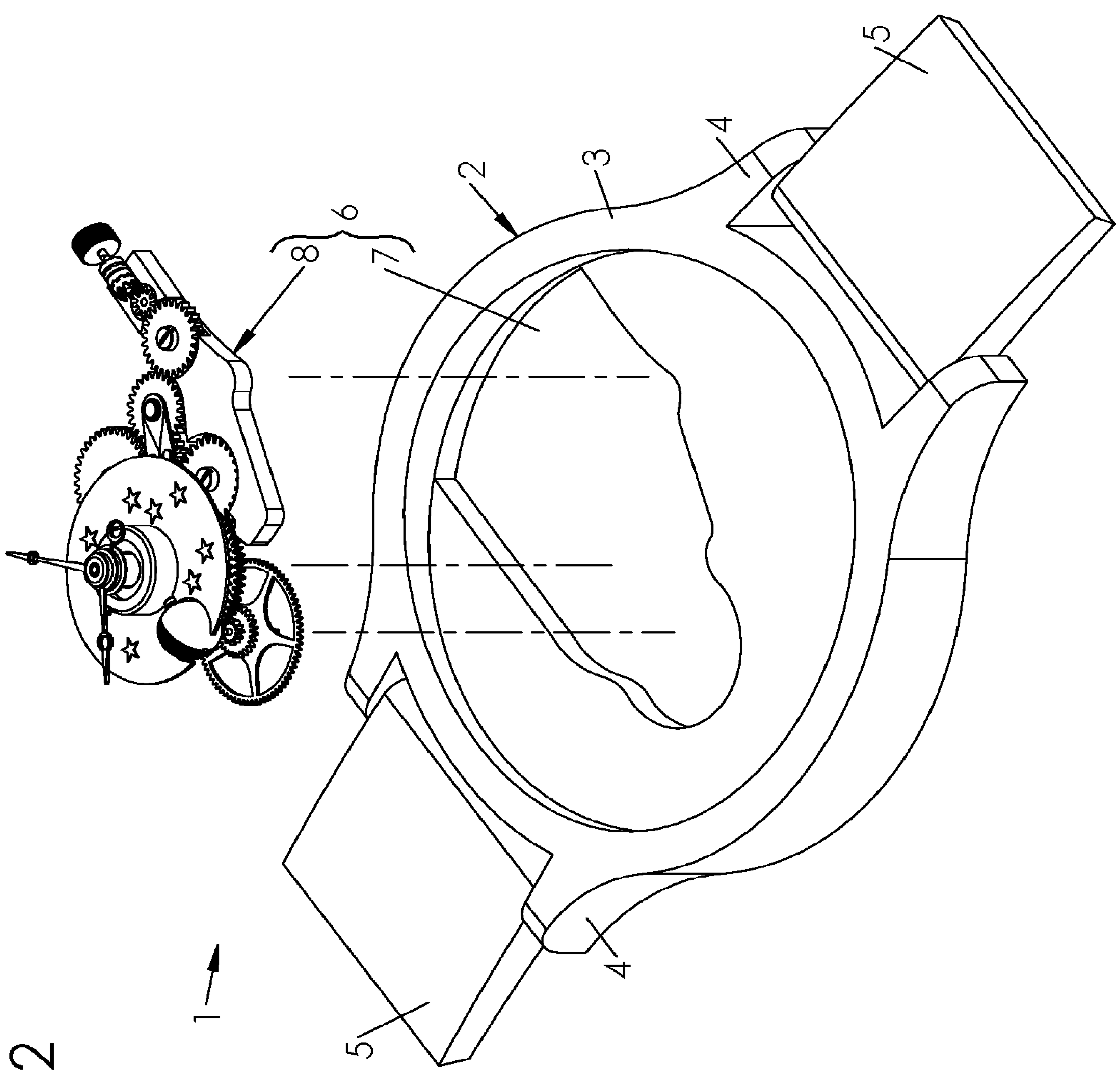


FIG.2

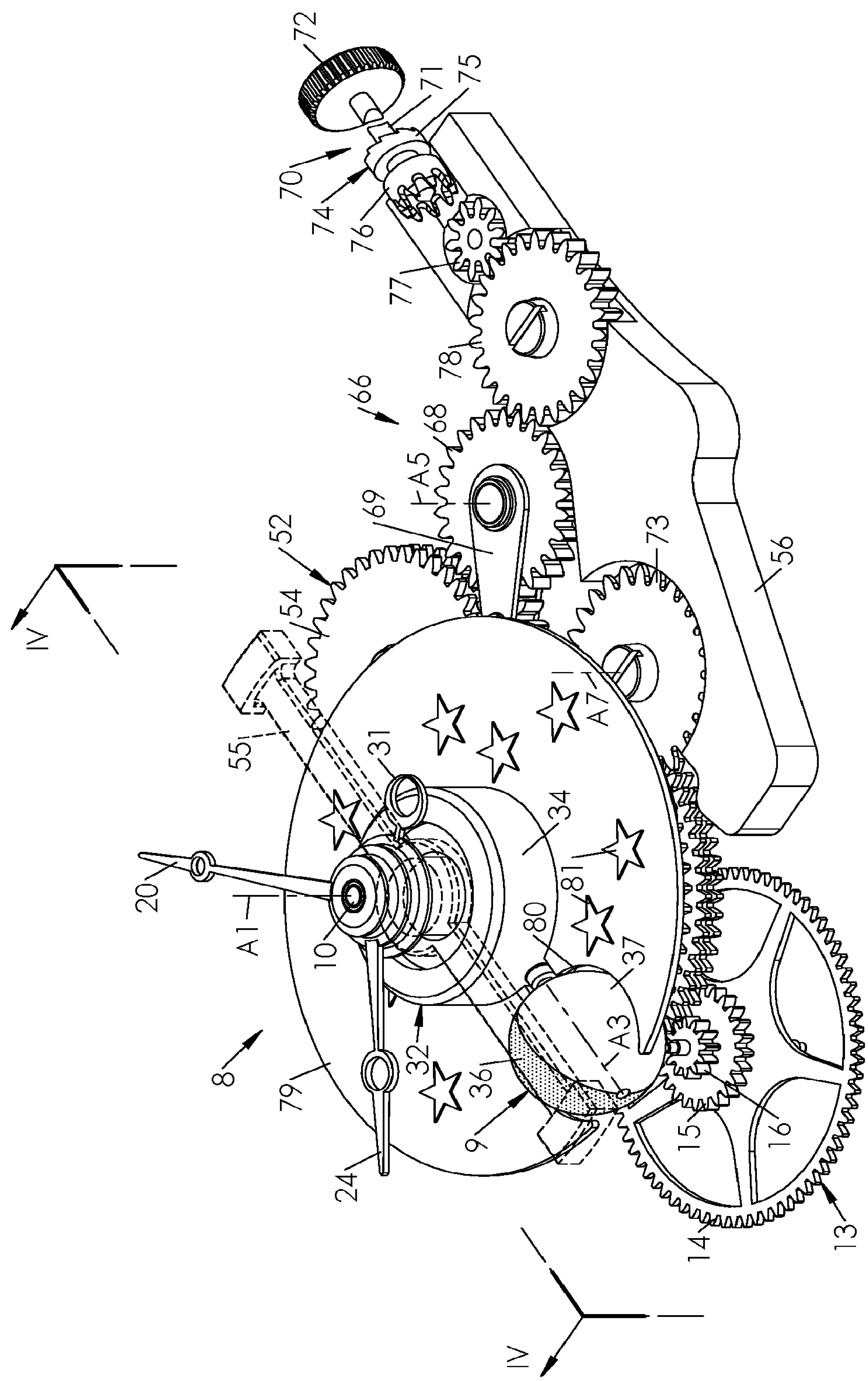

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FIG.3

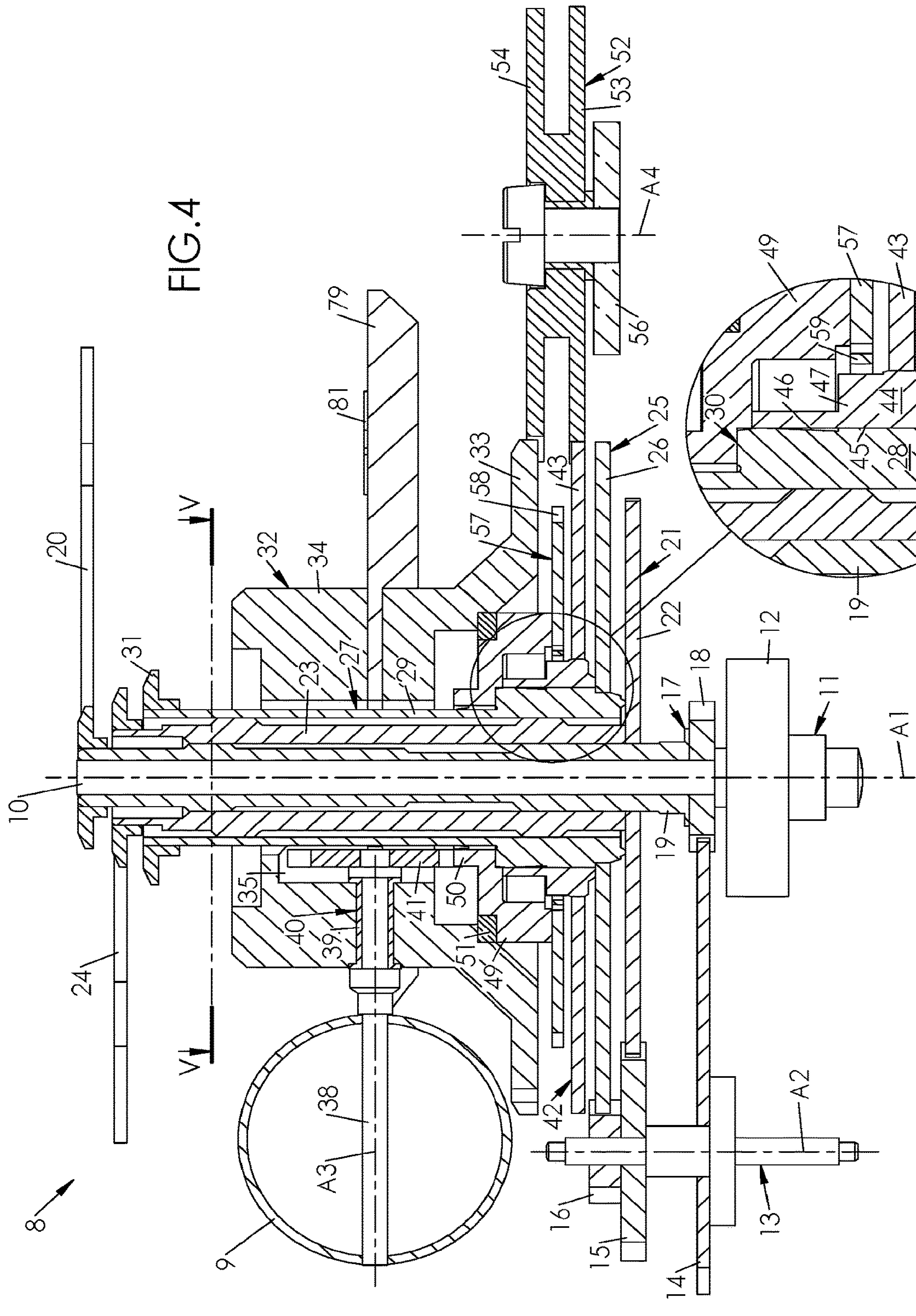
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FIG.4

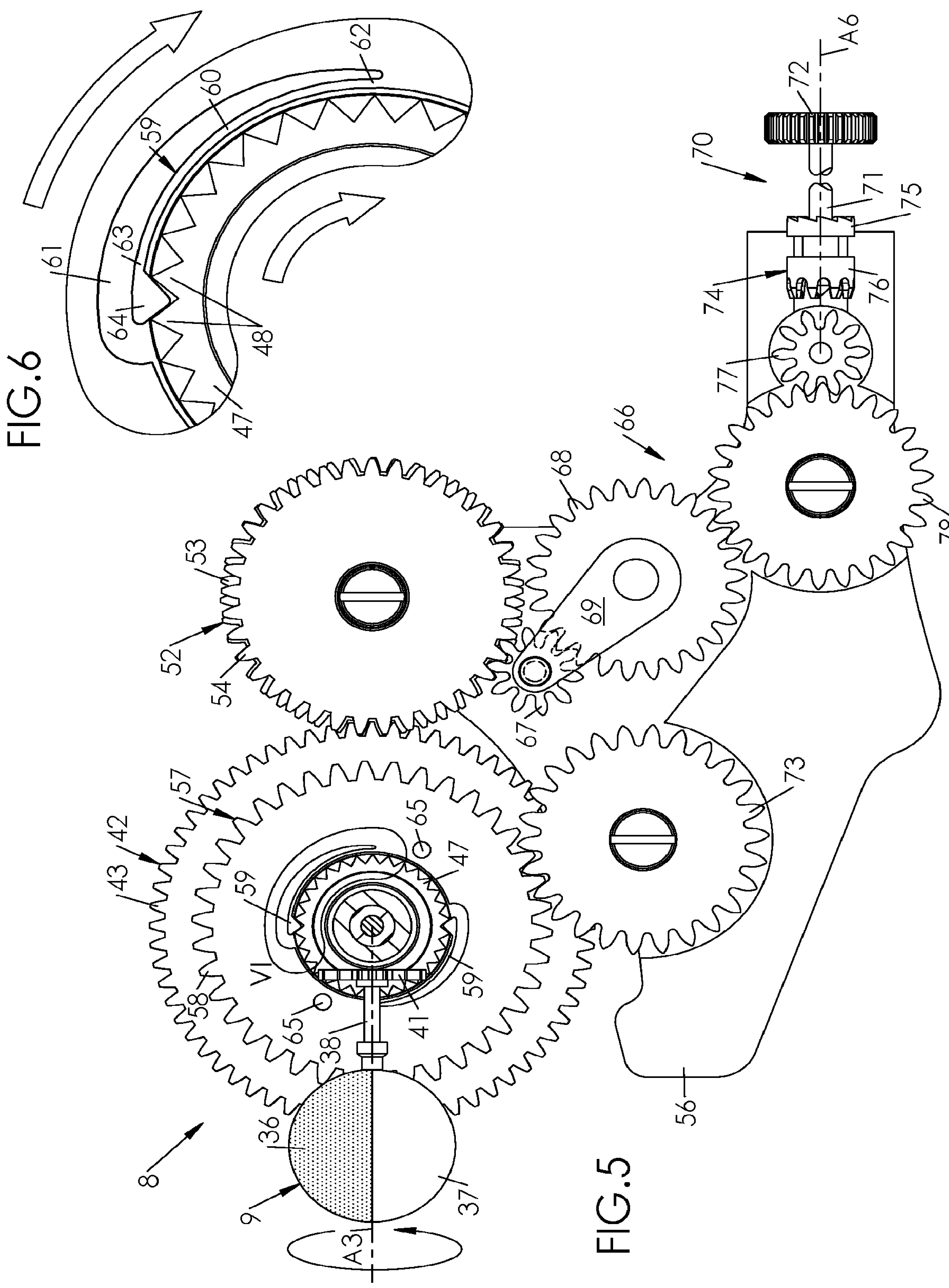

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FIG.6

FIG.5

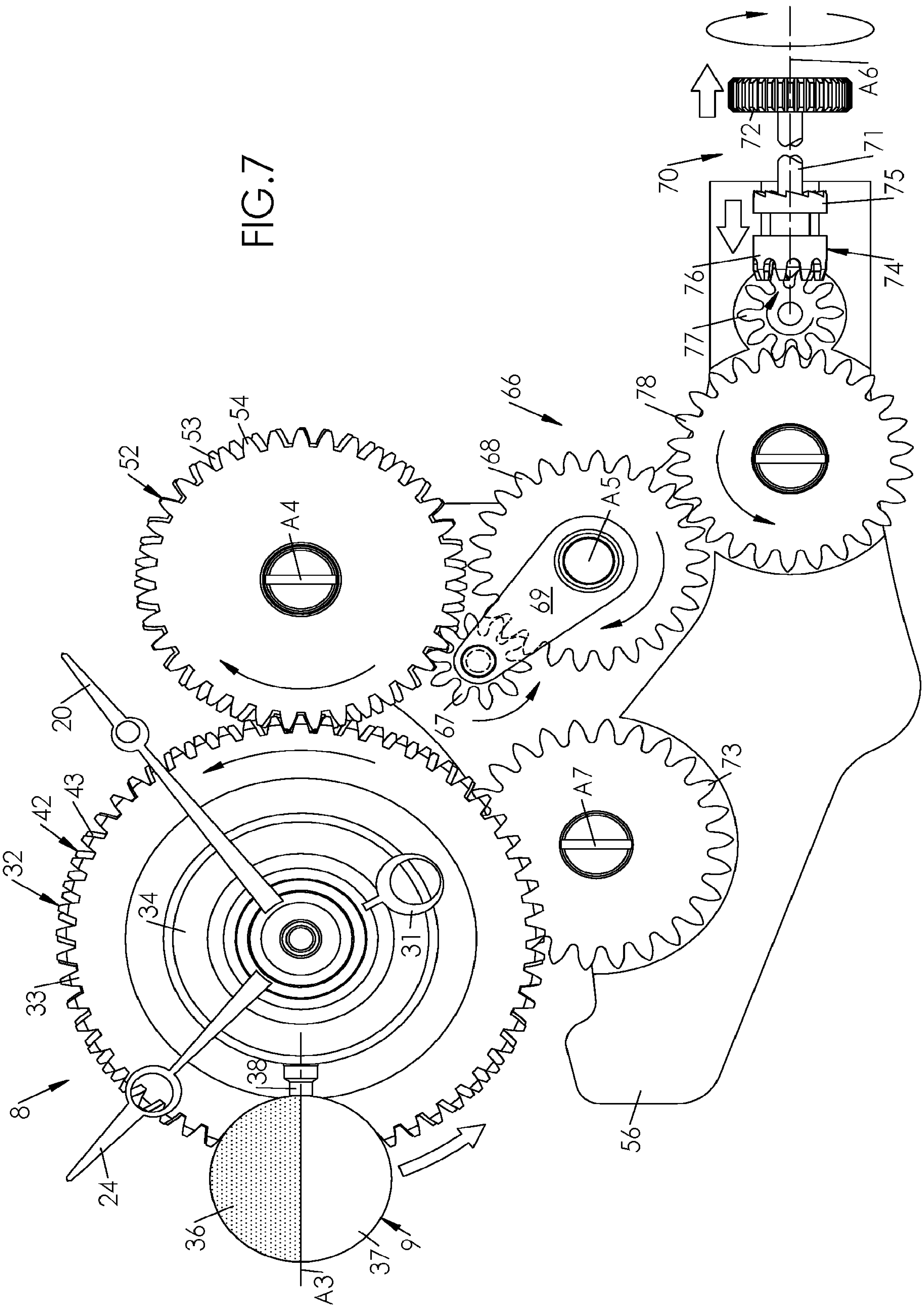
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FIG.7

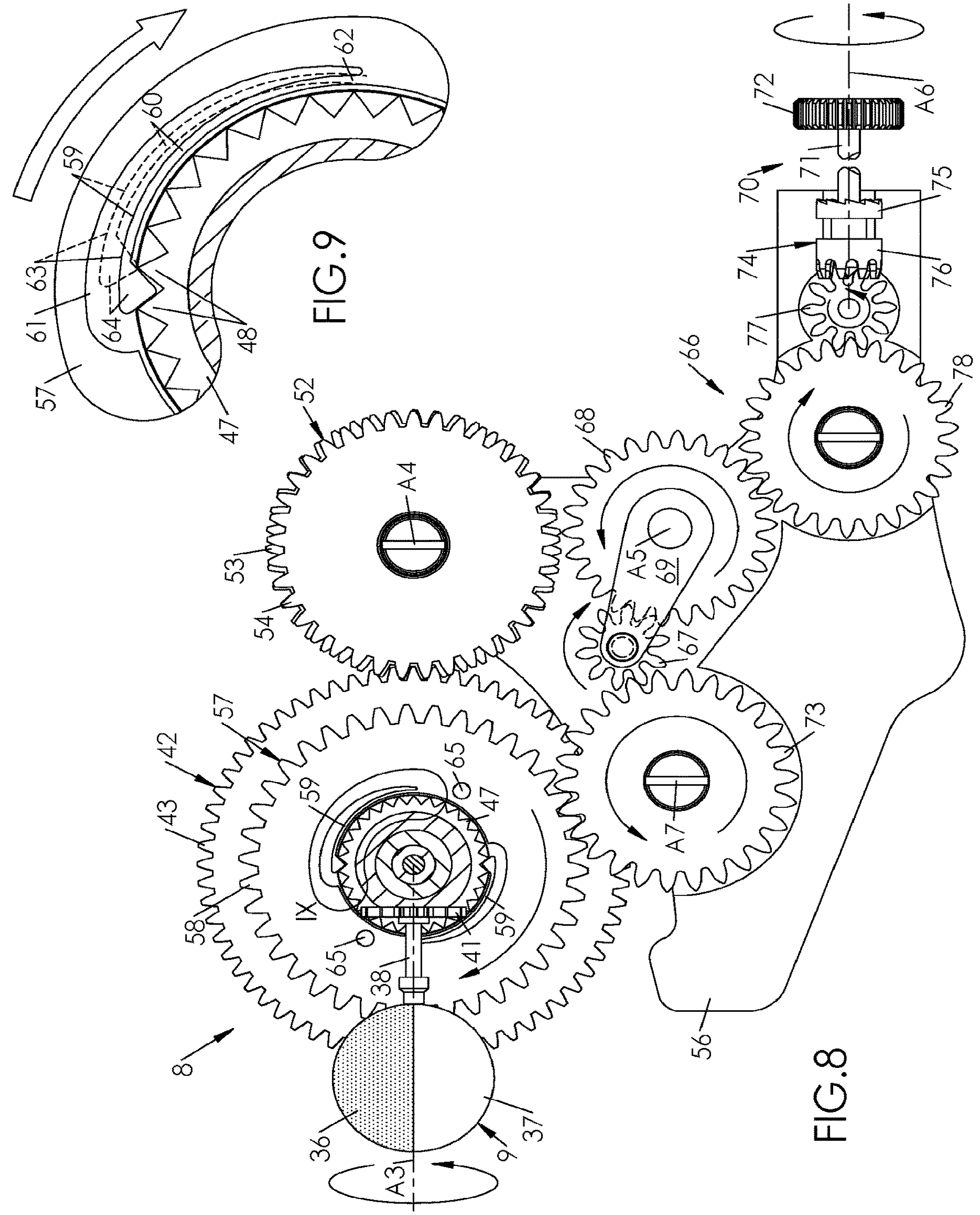

FIG.9

FIG.8

TIMEPIECE MECHANISM FOR DISPLAYING THE LUNAR DAY AND MOON PHASE, WITH A CORRECTION SYSTEM USING A DOUBLE KINEMATIC CHAIN

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority of European Patent Application No. 17201110.8 filed on Nov. 10, 2017 the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention concerns the field of horology. It concerns, more specifically, a mechanism, commonly called an astronomical complication, which allows the display of both:

- the lunar day, whose duration separates two successive crossings of a given meridian (which may be represented, in the clock or watch provided with the mechanism, by two successive midday crossings);
- and the moon phase, i.e. the (variable) portion of the moon illuminated by the sun.

BACKGROUND OF THE INVENTION

The astronomical features of the moon have been known for a long time and are notably described by James Ferguson in "Astronomy explained upon Sir Isaac Newton's principles", the fifth edition of which was published in 1772.

The mean value of the lunar day (separating two crossings of the meridian) is 24 hours, 50 minutes and 28.328 seconds.

The solar day to lunar day ratio is thus:

$$\frac{86400\ s}{89428.328\ s} = 0.96613682$$

As for the mean value of the lunation (the duration separating two full moons), this is 29 days, 12 hours, 44 minutes and 2.8 seconds.

Claiming to be inspired by Ferguson, E. Cloux, in his Horology course given at the Technical College of the Vallee de Joux (Switzerland) in 1949, drew a lunar day and moon phase display mechanism, in superposition on the solar day (with a mean value of 24 hours).

The mechanism drawn by E-Cloux, represented in FIG. **1**, included the following elements:

- a moon bearing **101** provided with a meridian wheel **102** (with 59 teeth) and rotatably mounted about a main axis **X1**;
- a sphere **103** representing the moon, rotatably mounted relative to moon bearing **101** about a radial axis X2 perpendicular to main axis **X1**; radial axis **Y1** carries a moon pinion **104** (with 20 teeth);
- a first rotating element **105** (with 57 teeth) rotatably mounted about main axis **X1** and which, it is understood, must mesh with a drive mechanism (not represented) also employed for displaying the minutes and/or hours of the solar day;
- a moon wheel set **106** (with two integral wheels each with 57 teeth) rotationally coupling, with gear reduction, first rotating element **105** to meridian wheel **102**;
- a central wheel **107** (with 20 teeth), integral with first rotating element **105** and meshing with moon pinion **104**.

This ingenious mechanism makes it possible to display the moon crossing the meridian in 24 hours, 50 minutes, 31.58 seconds, and a lunation in 29.5 days.

It is seen that these are approximations of the mean lunar day and the mean lunation, imposed by the choice of gear ratio:

$$24\ h{>}59/57{=}24\ h\ 50\ \text{min}\ 31.58\ s$$

However, the mechanism drawn by E. Cloux has no member for making corrections to the display that are made necessary either by deviations resulting from the aforecited approximations, or, quite simply, by the mechanism stopping once the power source is depleted (usually a mainspring in mechanical watches, which, if not rewound will unwind completely).

Consequently, it is an object of the invention to propose a solution which makes it possible to correct, in a simple and reliable manner, the lunar day and lunation in the mechanism presented above.

SUMMARY OF THE INVENTION

To achieve the aforecited object, there is proposed a timepiece mechanism for displaying the lunar day and the moon phase, which includes:

- a first rotating element rotatably mounted about a main axis and meshing with a drive mechanism,
- a moon bearing provided with a meridian wheel and rotatably mounted about a main axis,
- a sphere representing the moon, rotatably mounted relative to the moon bearing about a radial axis perpendicular to the main axis, the radial axis carrying a moon pinion,
- a moon wheel set rotationally coupling, with gear reduction, the first rotating element to the meridian wheel,
- a central wheel, rotatably mounted about a main axis on the first rotating element and meshing with the moon pinion,
- a second rotating element, meshing with the moon wheel set and friction mounted, at an interface, on the first rotating element to rotate integrally therewith about the main axis while the torque resulting from various circumferential forces respectively exerted on the first rotating element and on the second rotating element is lower, than a friction torque determining the maximum adhesion force at the interface, the second rotating element together with the moon wheel set and the moon bearing forming a first kinematic chain downstream of the first rotating element,
- a transmission wheel, integral in rotation with the central wheel and provided externally with a toothing and internally with at least one jumper spring engaging and meshing with the toothing of a star wheel integral in rotation with the second rotating element, to rotationally couple said second rotating element to the central wheel while the torque resulting from the various circumferential forces exerted respectively on the star wheel and on the transmission wheel is lower than a jump torque, beyond which the jumper spring is radially shifted by sliding over the star wheel until it is disengaged therefrom, said at least one jumper spring and the star wheel being configured such that the jump torque is lower than said friction torque, the transmission wheel together with the central wheel and the moon pinion forming a second kinematic chain downstream of the star wheel,

- a system for correcting the lunar day display, which includes a first drive element capable of having, at least momentarily, a meshing relationship with the first kinematic chain in order to force rotation of the moon bearing about the main axis, via a first correction train partially formed by at least one portion of the first kinematic chain, when a first correction torque, greater than said friction torque, is applied to said first correction train by a user, and
- a system for correcting the moon phase, which includes a second drive element capable of having, at least momentarily, a meshing relationship with the second kinematic chain in order to force rotation of the sphere about said radial axis, via a second correction train partially formed by at least one portion of the second kinematic chain and independent of the first kinematic chain, when a second correction torque, greater than said jump torque, is applied to said second correction train by a user.

As a result of this double correction system, which acts by using two distinct kinematic chains, it is possible to correct, in a simple and reliable manner, the lunar day display and the moon phase display.

According to a main embodiment, the lunar day display correction system and the moon phase correction system include a joint correction device for activating the lunar day display and, without activating the lunar day display, the moon phase. This joint correction device includes a sliding pinion which alone forms the first and second drive elements, said sliding pinion being able to adopt two adjustment positions, namely:

- a lunar day adjustment position, in which the sliding pinion meshes with the moon wheel set to force rotation of the moon bearing about said main axis via said at least one portion of the first kinematic chain;
- a moon phase adjustment position, in which the sliding pinion meshes with the transmission wheel to force rotation of the sphere about said radial axis via said at least one portion of the second kinematic chain.

The correction device advantageously includes a carrier pinion which meshes with the sliding pinion and at least one small connecting rod which joins the axes of rotation of the sliding pinion and of the carrier pinion.

The first rotating element includes, for example, a toothed wheel which extends perpendicularly to the main axis, integral with a pipe which extends along the main axis. The second rotating element then includes an auxiliary wheel which extends perpendicularly to the main axis, integral with a sleeve which is friction fitted onto the pipe of the first rotating element.

The friction connection between the second rotating element and the first rotating element is advantageously achieved by indenting, which for example takes the form of a one-off deformation of the internal diameter of the tube of the second rotating element, in order to ensure friction on the conical slot made in the pipe of the first element.

According to a preferred embodiment, the moon wheel set includes two superposed integral wheels, namely:

- a lower wheel, which meshes with the auxiliary wheel of the second rotating element, and
- an upper wheel, which meshes with the meridian wheel of the moon bearing.

According to a particular embodiment:

- the auxiliary wheel of the second rotating element has 64 teeth,
- the lower wheel of the moon wheel set has 43 teeth,
- the upper wheel of the moon wheel set has 37 teeth, and
- the meridian wheel of the moon bearing has 57 teeth.

The central wheel preferably carries a crown toothing meshed with the moon pinion; further, the central wheel is advantageously fitted onto the pipe of the first rotating element.

The moon bearing is preferably mounted on the central wheel, for example, fitted onto the latter with the insertion of a smooth bearing.

The transmission wheel advantageously includes a pair of diametrically opposite jumper springs.

Finally, the star wheel typically has 29 or 30 teeth, or, in a preferred variant, 59 teeth.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention will appear in light of the following description of one embodiment, made with reference to the annexed drawings, in which:

FIG. **1** is a cross-sectional view of a known mechanism for displaying the lunar day and moon phase, as proposed by E. Cloux.

FIG. **2** is an exploded perspective view illustrating a watch provided with a mechanism for displaying the lunar day and moon phase according to the invention.

FIG. **3** is a perspective, larger scale view of the display mechanism of FIG. **2**.

FIG. **4** is a partial cross-sectional view of the mechanism of FIG. **3**, along the cross-sectional plane IV-IV; an inset shows a larger scale detail.

FIG. **5** is a plan view of the mechanism of FIG. **4** (to show the underlying components, the moon bearing has been removed).

FIG. **6** is a larger scale view of a detail of the mechanism, taken at the same time in inset VI at the top left of FIG. **5**.

FIG. **7** is a top view of the mechanism, illustrating the lunar day correction.

FIG. **8** is a similar view to that of FIG. **5** illustrating the moon phase correction.

FIG. **9** is a larger scale view of a detail of the mechanism, taken in inset IX at the top left of FIG. **8**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **2** represents a timepiece. This could be a clock or a pendulum clock, but, in the illustrated example, it is a watch **1**—and more precisely a wristwatch, able to be worn on the wrist. In a conventional manner, this watch **1** includes a case **2** which includes a case middle **3**, a back cover and a crystal (not represented), and, fixed to the horns **4** of the case middle, a bracelet **5** for wear on the wrist.

Watch **1** includes, housed inside case **2**, a timepiece movement which includes a bottom plate **7** and, mounted on the plate, at least one timepiece mechanism **8** designed to ensure display of the lunar day and moon phase.

As we will see, mechanism **8** is also designed to ensure display of the minutes and hour of the mean solar day but such a display is optional and could be provided by a separate mechanism.

Mechanism **8** belongs to the family of 'astronomical' complications; it is organised around a main axis **A1** perpendicular to the general plane of plate **7**.

The moon is displayed as a body, in the form of a sphere **9** driven in a double movement:

- revolution about main axis **A1** to provide the lunar day indication;

rotation about a specific (radial) axis **A3** to provide the moon phase indication.

According to an embodiment illustrated in FIG. **4**, main axis **A1** is materialized by an arbor **10** which, in this example, is formed on a centre wheel set **11**, which is itself mounted on plate **7**. This central wheel set is provided here with a wheel **12** whose function is not relevant to the present context.

As seen in FIG. **4**, display mechanism **8** is engaged by a drive mechanism **13**, hereafter referred to as the motion-work, which includes several superposed rotationally integral wheels with a common axis **A2** which is offset relative to main axis **A1** and parallel thereto. In the illustrated example, motion-work **13** includes three superposed wheels, namely:

- a large wheel **14**, provided with a peripheral toothing typically having a number of teeth Z**1**=72;
- a medium wheel **15**, provided with a peripheral toothing typically having a number of teeth Z**2**=24;
- a small wheel **16**, provided with a peripheral toothing typically having a number of teeth Z**3**=12.

Motion-work **13** is driven in rotation by a drive device (not represented) including an energy source and a transmission. As astronomical complications are usually associated with mechanical watches, it is preferable for the energy source to be a mainspring associated with a balance/balance spring regulator. Nevertheless, if the energy source were a battery associated with a quartz resonator it would not be outside the scope of the invention.

As already mentioned, mechanism **8** is designed to display the minutes and the hour of the mean solar day.

For the minute display, mechanism **8** includes a cannon pinion **17**, rotatably mounted about main axis **A1** and provided with a centre pinion **18** meshing with large wheel **14**, and with a tube **19** fitted (with the possibility of rotation) onto arbor **10** of centre wheel set **11**. Cannon pinion **17** carries a minute hand **20** which, as illustrated in FIG. **4**, is pressed onto tube **19**, at an upper end of the latter. Centre pinion **18** is provided with a peripheral toothing typically including a number of teeth Z**4**=16. Cannon pinion **17** makes one revolution about main axis **A1** in one hour.

For the hour display, mechanism **8** includes an hour wheel set **21**, rotatably mounted about main axis **A1** and provided with an hour wheel **22** meshing with medium wheel **15**, and a hollow shaft **23** fitted (with the possibility of rotation) onto tube **19** of cannon pinion **17**. Hour wheel set **21** carries an hour hand **24** which, as illustrated in FIG. **4**, is driven onto hollow shaft **23**, at an upper end of the latter.

Hour wheel **22** is provided with a peripheral toothing typically having a number of teeth Z**5**=64, such that the gear reduction ratio (i.e. the ratio of rotational speeds) between hour wheel **22** and centre pinion **18** is:

$$\frac{Z4}{Z1} \times \frac{Z2}{Z5} = \frac{16}{72} \times \frac{24}{64} = \frac{1}{12}$$

Consequently, hour wheel set **21** makes one revolution about main axis **A1** in 12 hours.

For the lunar day and moon phase display, mechanism **8** includes, firstly, a first rotating element **25** rotatably mounted about main axis **A1** and meshing with motion-work **13**.

More specifically, in the example illustrated, in particular, in FIG. **4**, first rotating element **25** includes a toothed wheel, called solar wheel **26** (or 24-hour wheel), which extends perpendicularly to main axis **A1**, and a pipe **27**, integral with the solar wheel and which extends along main axis **A1**. According to one embodiment illustrated in FIG. **4**, pipe **27** is fitted (with the possibility of rotation) onto hollow shaft **23** of hour wheel set **21**.

In the illustrated example, pipe **27** is tiered, and includes a lower tier **28**, integral with solar wheel **26**, and an upper tier **29**, of smaller diameter than that of tier **28**. The lower tier and the upper tier are separated by a shoulder **30**.

Solar wheel **26** meshes with small wheel **16** of motion-work **13**. This solar wheel is provided with a peripheral toothing typically having a number of teeth Z**6**=64, such that the gear reduction ratio between first rotating element **25** and hour wheel set **21** is:

$$\frac{Z5}{Z2} \times \frac{Z3}{Z6} = \frac{64}{24} \times \frac{12}{64} = \frac{1}{2}$$

Consequently, first rotating element **25** makes one revolution about main axis **A1** in 24 hours. In other words, the first rotating element can be used to measure the mean solar day. It can also be employed to display the mean solar day. Thus, in the illustrated embodiment (cf. FIG. **3**), the first rotating element carries, at an upper end of upper tier **29** of pipe **27**, a solar hand **31** (also called a 24-hour hand), which may be round in shape and/or have a circular opening to represent the sun.

Mechanism **8** includes, secondly, a moon bearing **32** rotatably mounted about main axis **A1**. The moon bearing is provided with a meridian wheel **33**. The moon bearing is also provided with a moon cover **34**, fixed to the meridian wheel to rotate integrally therewith. In a variant, the meridian wheel and the moon cover form a one-piece part.

Meridian wheel **33** is provided with a peripheral toothing typically having a number of teeth Z**7**=57.

As seen in FIG. **4**, moon bearing **32** is hollow, and has an internal cavity **35** arranged inside moon cover **34**.

Mechanism **8** includes, thirdly, a sphere **9** representing the moon, rotatably mounted relative to moon bearing **32** about a radial axis **A3** perpendicular to main axis **A1**. Sphere **9** advantageously has two hemispheres of contrasting colours, namely:

- a dark hemisphere **36** (grey in the drawings), representing the portion of the side of the moon not illuminated by the sun;
- a light coloured hemisphere **37** (white in the drawings), representing the portion of the moon illuminated by the sun.

Hemispheres **36**, **37** can be made distinct by applying paint. However, in a preferred embodiment, the hemispheres are half-spherical calottes made from different materials and assembled to form sphere **9**. Thus, dark hemisphere **36** can be made from biotite mica, obsidian or any other dark mineral, while light hemisphere **37** can be made of metal (for example silver or grey gold), or from a light-coloured mineral (for example moonstone).

Further, in the illustrated example, radial axis **A3** is formed by a runner **38** that passes through sphere **9** and rotates integrally therewith. At an inner end, the runner is mounted in a sleeve **39** fitted into a hole **40** made in moon bearing **32**.

As seen in FIG. **4**, radial axis **A3** (i.e. runner **38**) carries, at an inner end, a moon pinion **41**, which is rotates integrally therewith. The moon pinion is housed inside inner cavity **35** of moon bearing **32**.

Moon pinion **41** is provided with a peripheral toothing typically having a number of teeth Z**8**=14.

Mechanism **8** includes, fourthly, a second rotating element **42**, rotatably mounted about main axis A**1**. According to an embodiment illustrated in FIG. **4**, the second rotating element includes an auxiliary wheel **43**, which extends perpendicularly to main axis A**1**, and a sleeve **44** integral with the auxiliary wheel and which extends along main axis A**1**. Auxiliary wheel **43** is provided with a peripheral toothing typically having a number of teeth Z**9**=64 teeth.

Second rotating element **42** is mounted on first rotating element **25** with friction at their interface, referenced **45** (the interface is the surface where the first rotating element and the second rotating element make contact).

More precisely, sleeve **44** is friction fitted onto pipe **27** of the first rotating element. Even more precisely, the sleeve is friction fitted onto the lower tier **28** of the pipe. This friction fit is intended to make second rotating element **42** integral (in rotation about main axis A**1**) with first rotating element **25**, while the torque, referenced C**1**, resulting from various circumferential forces respectively exerted on the first rotating element and on the second rotating element is lower than a friction torque, referenced CF, which determines the maximum adhesion force at interface **45**.

In other words:

while C**1**<CF, first rotating element **25** and second rotating element **42** rotate integrally, with no sliding at their interface **45**, and behave like a one-piece part;

as soon as C**1**≥CF, the maximum adhesion force at interface **45** between first rotating element **25** and second rotating element **42** is reached, and they become rotationally separate, such that the second rotating element can pivot independently of the first rotating element about main axis A**1**, with sliding at interface **45**.

The friction connection at interface **45** between the second rotating element and the first rotating element can, in practice, be achieved by an indent **46**, which takes the form, for example, as illustrated in the detailed inset of FIG. **4**, of a conical groove made in pipe **27** of the first rotating element.

Second rotating element **42** is provided with a star wheel **47**. This peripherally formed star wheel **47**, is, for example, cut externally in sleeve **44**. It includes a series of triangular teeth **48**, which are 30 in number here, but could be 29 in number, or even 59 in number (which is the approximate number of half-days in one lunation).

Mechanism **8** includes, fifthly, a central wheel **49**, mounted on first rotating element **25** and geared with moon pinion **41**. This central wheel advantageously carries a crown toothing **50** (i.e. whose teeth extend parallel to main axis A**1**) meshed with moon pinion **41**. This toothing is, for example, cycloidal and has a number of teeth Z**10** equal to the number of teeth Z**8** of the moon pinion (namely Z**10**=14 here).

In the example illustrated in FIG. **4**, central wheel **49** is fitted onto pipe **27** of first rotating element **25**. More precisely, the central wheel is fitted onto shoulder **30**. The interface between the central wheel and the first rotating element is a sliding interface, so that the central wheel can rotate independently of the first rotating element.

According to a preferred embodiment illustrated in FIG. **4**, moon bearing **32** is mounted on central wheel **49**. To allow rotation of moon bearing **32** relative to the central wheel, a smooth bearing **51** is inserted therebetween.

Mechanism **8** includes, sixthly, a moon wheel set **52** which rotationally couples, with gear reduction, first rotating element **25** to meridian wheel **33** (and thus to moon bearing **32**) to allow the moon bearing to be rotated by first rotating element **25**. More precisely, moon wheel set **52** rotationally couples second rotating element **42** (integral in rotation with first rotating element **25** while C**1**<CF) to the meridian wheel.

Moon wheel set **52** is offset, rotatably mounted about an axis A**4** parallel to main axis A**1**. According to an embodiment illustrated in FIG. **4**, the moon wheel set includes two superposed integral wheels, namely:

a lower wheel **53**, which meshes with auxiliary wheel **43** of second rotating element **42**;

an upper wheel **54**, which meshes with meridian wheel **33** of moon bearing **32**.

Lower wheel **53** is provided with a peripheral toothing typically having a number of teeth Z**11**=43. Upper wheel **54** is provided with a peripheral toothing typically having a number of teeth Z**12**=37 teeth. Consequently, the gear reduction ratio, referenced R, of solar wheel **26** to meridian wheel **33** (equal to the rotational speed ratio of moon bearing **32** to first rotating element **25**) is:

$$R = \frac{Z9}{Z11} \times \frac{Z12}{Z7} = \frac{64}{43} \times \frac{37}{57} = 0.96613627$$

This gear reduction ratio provides the displayed mean lunar day value, referenced J:

$$J = \frac{24\text{ h}}{R} = 24\text{ h } 50\text{ min } 28.378\text{ s}$$

This is an excellent approximation of the real mean lunar day. Indeed, the lunar day displayed shows a loss of only 5/100ths of a second per solar day relative to the real lunar day (i.e. one day of loss every eight years).

The lunar day display is ensured by the circular path (i.e. the revolution) of sphere **9** about main axis A**1**. The moon crossing the zenith is represented by sphere **9** crossing twelve o'clock.

According to a preferred embodiment, illustrated in dotted lines in FIG. **3**, the watch is advantageously provided with a bar **55**, visible to the wearer, and which represents the earth's horizon line.

The path of approximately 180° of sphere **9** above bar **55** (from the point of view of the wearer) represents the moon's path in the visible sky (lunar day), while the path of approximately 180° of sphere **9** below the bar represents the moon's path in the non-visible sky (lunar night).

Moon wheel set **52** is advantageously mounted on a bridge **56** which is itself fixed to plate **7**. Its axis of rotation A**4** is, for example, materialized by a screw in helical engagement with bridge **56**.

Mechanism **8** includes, seventhly, a transmission wheel **57** integral with central wheel **49**, designed to make the latter rotate integrally with second rotating element **42** during normal operation of mechanism **8**, and conversely, to allow rotation of one relative to the other when the display is corrected, in conditions which will be set out below.

Transmission wheel **57** is provided externally with a toothing **58** and internally with at least one jumper spring **59**.

According to an embodiment illustrated in FIG. **8**, transmission wheel **57** is provided with a pair of diametrically opposite jumper springs **59**. This number is not limiting. Thus, three jumper springs arranged at 120° could be provided.

As illustrated in FIG. **6** and FIG. **9**, the (or each) jumper spring **59** includes a strip spring **60** (curved in the illustrated example), which extends into a hollow **61** made in transmission wheel **57**. Seen from above, strip spring **60** extends from a fixed end **61** to a free end **63** in the anticlockwise direction (cf. FIG. **6**). Jumper spring **59** is also provided, at the free end of the strip spring, with a triangular head **64** of complementary size and shape to the space separating two adjacent teeth **48** of star wheel **47**.

The (or each) jumper spring **59** is engaged and mesh (via its head **64**) with the toothing of star wheel **47**. In its position of equilibrium (in the absence of any stress), jumper spring **59** would occupy a position in which head **64** is separated from main axis A**1** by a distance smaller than the radius of the star wheel.

In normal operation, the (or each) jumper spring **59** is retained by its head **64** between two adjacent teeth **48** of star wheel **47**. Jumper spring **59** is held in this position by its own elastic return force which tends to draw head **64** in the direction of main axis A**1**.

During normal operation, second rotating element **42**, which is integral with first rotating element **25** (and thus driven therewith in rotation) rotates about main axis A**1** in the clockwise direction (seen from above). Star wheel **47** consequently exerts on head **64** of the (or of each) jumper spring **59** a stress that causes the latter to butt, which tends to keep head **64** between two adjacent teeth **48** of the star wheel. In these conditions, the second rotating element (with the first rotating element) and transmission wheel **57** (with central wheel **49**) are integral in rotation about main axis A**1** and rotate together in the clockwise direction about the latter (FIG. **6**).

Central wheel **49** is made integral with transmission wheel **57**, for example by means of feet **65**, protruding onto the central wheel, driven into holes made in transmission wheel **57**. In a variant, this attachment can be achieved using screws.

During a correction of the moon phase display, a drive torque is applied to transmission wheel **57** to drive it in rotation about main axis A**1** (in the anticlockwise direction when seen from above, cf. FIG. **8** and FIG. **9**) without, however, this rotation being transmitted by star wheel **47** to second rotating element **42**.

Second rotating element **42**, friction mounted on first rotating element **25**, resists the rotation of transmission wheel **57**, and the torque resulting from the various circumferential forces exerted respectively on first rotating element and on transmission wheel **57** is referenced C**2**.

It is at this point that the elasticity of jumper spring(s) **56** plays a part. Each jumper spring **59** is set—i.e. dimensioned—to:

- remain locked meshed with star wheel **47** while torque C**2** is lower than a jump torque CS;
- be radially shifted by sliding over star wheel **47** (and more precisely by head **64** sliding over teeth **48**) until it is disengaged, as illustrated in dotted lines in FIG. **9**, as soon as torque C**2** becomes greater than jump torque CS. It will be noted that this radial shift is permitted by the flexibility of strip spring **60**.

Jump torque CS is lower than friction torque CF, i.e.:

$$CS<CF$$

Consequently, the application of torque C**2** alone can never cause second rotating element **42** to slide relative to first rotating element **25**. The first and second rotating elements therefore remain integral in rotation (and thus immobile) during a moon phase correction.

During normal operation, central wheel **49** (with crown toothing **50**) rotates integrally with the second rotating element (and thus with the first rotating element) at a rate of one complete revolution about main axis A**1** in 24 hours.

Given gear reduction ratio R presented above, moon bearing **32** (with sphere **9**) makes its own complete revolution more slowly (in 24 hours, 50 minutes and 28.378 seconds), And, given the fact that moon pinion **41** and crown toothing **50** include the same number of teeth (Z**8**=Z**10**), sphere **9** is driven slowly in rotation about radial axis A**3** (in the clockwise direction when mechanism **8** is observed from the side, in the direction of radial axis A**3**).

Sphere **9** makes one complete rotation about its axis A**3** in a number L of days corresponding to the displayed lunation value, i.e.:

$$L=\frac{1}{1-R}=29.53012048=29\ j\ 12\ \text{h}\ 43\ \text{min}\ 22.4\ \text{s}$$

This is an excellent approximation of the real lunation, with a loss of around 7 minutes per month compared to said real lunation (i.e. one day of loss every 17 years).

We have seen that the differences between the displayed lunar day and the real lunar day, on the one hand, and the displayed moon phase and the real moon phase on the other hand, are small. One lunar day correction and one lunation correction would be required after several years of uninterrupted operation of watch **1**.

However, users who are diligent enough not to let the power reserve of a mechanical watch become depleted are rare. Thus, corrections required to reset the displays after watch **1** has stopped due to absent-mindedness of the user are more frequent than corrections required to make up losses accumulated by mechanism **8** during uninterrupted operation.

To correct the lunar day display, mechanism **8** is provided with a correction device **66** including a pinion **67** able to mesh with moon wheel set **52** to force rotation of moon bearing **32** about main axis A**1** via a first correction train which bypasses transmission wheel **57** and which includes moon wheel set **52** and meridian wheel **33**.

To correct the moon phase display, mechanism **8** is provided with a correction device **66** which includes a pinion **67** able to mesh with transmission wheel **57** to force rotation of sphere **9** about radial axis A**3** via a second train which includes the transmission wheel, central wheel **49** and moon pinion **41**.

Mechanism **8** could have two distinct correction devices to correct the lunar day display and the moon phase display separately. To activate them separately, watch **1** could be provided with two distinct winding mechanisms that could be operated independently of one another by the user (or a watchmaker).

However, in a preferred embodiment illustrated in the drawings, and more particularly in FIG. **5**, FIG. **7** and FIG. **8**, mechanism **8** includes a single device **66** for correcting the lunar day and moon phase display.

This correction device **66** includes a sliding pinion **67** able to adopt two adjustment positions, namely:

- a lunar day adjustment position, in which sliding pinion **67** meshes with moon wheel set **52** to force rotation of moon bearing **32** about main axis A**1** via the first kinematic chain (FIG. **7**);

a moon phase adjustment position, in which sliding pinion **67** meshes with transmission wheel **57** to force rotation of sphere **9** about radial axis A**3** via the second kinematic chain (FIG. **8**).

In the example illustrated in FIG. **7** and FIG. **8**, correction device **66** includes a carrier pinion **68** which meshes with sliding pinion **67** and at least one connecting rod **69** which joins the axes of rotation of the sliding pinion and of the carrier pinion. In practice, correction device **66** includes a pair of superposed connecting rods **69**, arranged on either side of the carrier pinion and the sliding pinion.

Carrier pinion **68** is rotatably mounted on bridge **56** about an axis A**5** parallel to main axis A**1** and advantageously materialized by a screw helically engaged with bridge **56**.

Correction device **66** includes a winding mechanism **70** provided with a stem **71** mounted in a sliding pivot arrangement about and along a winding axis A**6** perpendicular to main axis A**1**, and with a crown **72** integral in rotation with stem **71**. The stem passes through case middle **3** and the crown is accessible to the user.

According to a particular embodiment illustrated in FIG. **8**, correction device **66** includes a toothed, intermediate, phase wheel (hereinafter more simply referred to as intermediate phase wheel **73**) which meshes with transmission wheel **57** and via which, in the moon phase adjustment position, sliding pinion **67** meshes with the transmission wheel. The intermediate phase wheel is rotatably mounted on the bridge about an axis A**7** materialized by a screw helically engaged with bridge **56**.

Correction device **66** also includes a sliding member **74** provided with a winding pinion **75** (for example with a Breguet toothing) and a sliding pinion **76**, mounted in a sliding pivot arrangement about and along winding axis A**6**, and coupled to winding mechanism **70**, for example by a traditional pull out piece and lever mechanism (not represented), between:

a correction position (FIG. **7** and FIG. **8**) in which sliding pinion **76** is coupled to carrier pinion **68**, and

a position of release in which sliding pinion **76** is uncoupled from carrier pinion **68** (and in which winding pinion **75** is coupled to a winding pinion that is not represented, via which the mainspring of watch **1** is wound by rotating winding crown **72**).

Transmission of the rotation of winding mechanism **70** to carrier pinion **68** is advantageously achieved via an intermediate train, which typically includes a first intermediate wheel **77**, meshed with sliding pinion **76**, and a second intermediate wheel **78**, inserted between the first intermediate wheel and the carrier pinion.

Finally, in an embodiment illustrated in particular in FIG. **2** and FIG. **4**, mechanism **8** includes a covering **79** in the form of a disc integral with moon bearing **32** (and for example sandwiched between meridian wheel **33** and moon cover **34**). Covering **79** has an opening **80** of circular shape inside which is housed sphere **9**. This covering, which rotates with moon bearing **32**, is intended to symbolise the celestial vault. To this end, in the illustrated example, cover **79** carries symbols **81** (etched, painted, or in relief) representing a constellation of stars.

Correction of the lunar day display causes a rotation of sphere **9** about its axis A**3** and consequently a change in the moon phase display. This is why correction of the lunar day display must precede correction of the moon phase display.

Prior to any correction, cam **74** must be placed in the correction position, by pulling (in a conventional manner for the user or watchmaker) winding crown **72**, which pushes sliding pinion **76** towards first intermediate wheel **77** to place them in mesh.

To correct the lunar day display, winding crown **72** must be rotated in a determined direction which depends on the number of pinions in intermediate train **77**, **78**. In the embodiment illustrated in FIG. **7**, the winding crown must be rotated in the clockwise direction seen along winding axis A**6**.

Rotation of winding crown **72** then drives, via intermediate train **77**, **78**, carrier pinion **68** in the clockwise direction (seen from above), which also tends to pivot connecting rods **69** in the clockwise direction and causes (or maintains) the meshing of sliding pinion **67** with moon wheel set **52**.

The clockwise rotation of carrier pinion **68** then successively drives in rotation:

sliding pinion **67**, meshed with carrier pinion **68**, in the anticlockwise direction;

moon wheel set **52**, meshed with sliding pinion **67**, in the clockwise direction,

moon bearing **32**, whose meridian wheel **33** is meshed with upper wheel **54** of the moon wheel set, in the anticlockwise direction.

As a result, sphere **9** is driven in a movement of revolution about main axis A**1** in the anticlockwise direction. All these movements are illustrated by the arrows in FIG. **7**.

It will be noted that, during the lunar day correction, the resulting torque C**2** which is exerted on auxiliary wheel **43** exceeds friction torque CF, such that, while first rotating element **25** remains rotationally immobile about axis A**1** (since it is blocked by motion work **13**), indent **46** yields and allows the auxiliary wheel to slide relative to pipe **27** at their interface **45**.

The rotation of the winding crown **72** is stopped when the angular position of radial axis A**3** of sphere **9** about main axis A**1** is deemed to be correct, which ends the lunar day display correction.

The moon phase display must then be corrected. To do so, winding crown **72** must be rotated in the opposite direction to the direction followed during correction of the lunar day display. In the example illustrated in FIG. **8**, winding crown **72** must be rotated in the anticlockwise direction seen from along winding axis A**6**.

The rotation of winding crown **72** drives, via intermediate train **77**, **78**, carrier pinion **68** in the anticlockwise direction (seen from above), which also tips connecting rods **69** in the anticlockwise direction until sliding pinion **67** meshes with intermediate phase wheel **73**.

As the rotation of winding crown **72** continues, the anticlockwise rotation of carrier pinion **68** successively drives in rotation:

sliding pinion **67**, meshed with carrier pinion **68**, in the anticlockwise direction;

intermediate phase wheel **73**, meshed with the sliding pinion, in the clockwise direction.

As soon as torque C**2** attains jump torque CS (which the user or watchmaker's fingers are quite capable of causing to happen), transmission wheel **57**, whose toothing **58** is meshed with intermediate phase wheel **73**, is itself driven in rotation in the clockwise direction. All these movements are illustrated by the arrows in FIG. **8**.

However, jump torque CS is lower than the friction torque CF of second rotating element **42** on first rotating element **25**. Consequently, despite the rotation of transmission wheel **57**, the second rotating element remains immobile, since it is integral in rotation with the first rotating element, which is locked by motion-work **13**.

Consequently, the jumper or jumpers **59** is/are shifted radially and jump from one tooth to the next as transmission wheel **57** rotates, as illustrated in dotted lines in FIG. **9**.

Central wheel **49**, integral in rotation with transmission wheel **57**, is driven, with its toothing **50**, in rotation about axis A**1** in the clockwise direction. As moon bearing **32** remains immobile, this rotation of the central wheel causes, via moon pinion **41** with which it meshes, rotation of sphere **9** about its radial axis A**3**, in the clockwise direction (seen from along axis A**3**).

In a first variant, by adding, for example, an additional wheel set to the moon phase correction train between the transmission wheel and the sliding pinion, the sphere then rotates in the anticlockwise direction, which corresponds to its direction of rotation in normal operation. In a second variant, assuming that, during a lunar day correction, sphere **9** is driven in a movement of revolution about main axis A**1** in the clockwise direction, then the additional wheel set can be inserted in the kinematic chain of correction device **66**. By way of alternative, in a third variant, one wheel set is removed from the kinematic chain of correction device **66**. Finally, it is also possible to obtain a moon phase correction by reversing the relative position of the moon wheel set and the transmission wheel, the moon phase correction would then be made by rotating the crown in the clockwise direction, whereas the lunar day correction would be made by rotating the crown in the anticlockwise direction.

When star wheel **47** has 29 or 30 teeth, each jump of jumper spring(s) **59** from one tooth to the other corresponds to a correction of one day. When the star wheel has 59 teeth, each jump of the jumper spring(s) from one tooth to the other corresponds to a half-day correction. The wearer or watchmaker is informed of this correction (of one day or respectively a half-day) by the click sound that accompanies the jump of the jumper spring(s).

Once corrections to the lunar day display and the moon phase display are completed, the wearer pushes winding crown **72** back in, which moves cam **74** in translation, uncoupling sliding pinion **76** from first intermediate wheel **77**.

During normal operation of watch **1**, it is not inconvenient for sliding pinion **67** to remain meshed with moon wheel set **52** (as illustrated in FIG. **5**) or with intermediate phase wheel **73**, since winding mechanism **70** is uncoupled from carrier pinion **68**.

It is seen that the correction device **66** presented above makes it possible, in a simple, efficient, precise and reliable manner, to correct the lunar day and moon phase in mechanism **8**. For the wearer or the watchmaker, the direction of rotation alone determines the correction applied.

The invention claimed is:

1. A timepiece mechanism for displaying a lunar day and a moon phase, comprising:

- a first rotating element rotatably mounted about a main axis and meshing with a drive mechanism;
- a moon bearing provided with a meridian wheel and rotatably mounted about the main axis;
- a sphere representing the moon, rotatably mounted relative to the moon bearing about a radial axis perpendicular to the main axis, the radial axis bearing a moon pinion;
- a moon wheel set rotationally coupling, with gear reduction, the first rotating element to the meridian wheel;
- a central wheel, rotatably mounted about the main axis on the first rotating element and meshing with the moon pinion;
- a second rotating element, meshing with the moon wheel set and friction mounted, at an interface, on the first rotating element to rotate integrally therewith about the main axis while the torque resulting from various circumferential forces respectively exerted on the first rotating element and on the second rotating element is lower than a friction torque determining the maximum adhesion force at the interface, the second rotating element together with the moon wheel set and the moon bearing forming a first kinematic chain downstream of the first rotating element;
- a transmission wheel, integral in rotation with the central wheel and provided externally with a toothing and internally with at least one jumper spring engaging and meshing with the toothing of a star wheel integral in rotation with the second rotating element, to rotationally couple said second rotating element to the central wheel while the torque resulting from various circumferential forces exerted respectively on the star wheel and on the transmission wheel) is lower than a jump torque, beyond which the jumper spring is radially shifted by sliding over the star wheel until it is disengaged therefrom, said at least one jumper spring and the star wheel being configured such that the jump torque is lower than said friction torque, the transmission wheel together with the central wheel and the moon pinion forming a second kinematic chain downstream of the star wheel;
- a system for correcting the lunar day display, which includes a first drive element capable of having, at least momentarily, a meshing relationship with the first kinematic chain in order to force rotation of the moon bearing about the main axis, via a first correction train partially formed by at least one portion of the first kinematic chain, when a first correction torque, greater than said friction torque, is applied to said first correction train by a users; and
- a system for correcting the moon phase, which includes a second drive element capable of having, at least momentarily, a meshing relationship with said second kinematic chain in order to force rotation of the sphere about the radial axis, via a second correction train partially formed by at least one portion of the second kinematic chain and independent of the first kinematic chain, when a second correction torque, greater than said jump torque, is applied to said second correction train by a user.

2. The timepiece mechanism according to claim **1**, wherein the lunar day display correction system and the moon phase correction system include a joint correction device for activating the lunar day display, and without activating the lunar day display, the moon phase, said joint correction device includes a sliding pinion which alone forms the first and second drive elements, said sliding pinion being able to adopt two adjustment positions including,

- a lunar day adjustment position, in which the sliding pinion meshes with the moon wheel set to force rotation of the moon bearing about the main axis via said at least one portion of the first kinematic chain, and
- a phase adjustment position, in which the sliding pinion meshes with the transmission wheel to force rotation of the sphere about the radial axis via said at least one portion of the second kinematic chain.

3. The timepiece mechanism according to claim **2**, wherein the joint correction device includes a carrier pinion which meshes with the sliding pinion and at least one connecting rod which joins the axes of rotation of the sliding pinion and of the carrier pinion.

4. The timepiece mechanism according to claim **1**, wherein the star wheel and the second rotating element are coaxial and integral and in that the transmission wheel and the central wheel are coaxial and integral.

5. The timepiece mechanism according to claim **1**, wherein the first drive element is able to mesh with the moon wheel set at least during a correction of the lunar day display, and the second drive element is able to mesh with the transmission wheel at least during a correction of the moon phase.

6. The timepiece mechanism according to claim **1**, wherein the first rotating element includes a toothed wheel which extends perpendicularly to the main axis, integral with a pipe that extends along the main axis.

7. The timepiece mechanism according to claim **6**, wherein the second rotating element includes an auxiliary wheel which extends perpendicularly to the main axis, integral with a sleeve which is friction fitted onto the pipe of the first rotating element.

8. The timepiece mechanism according to claim **7**, wherein the moon wheel set includes two superposed integral wheels, two superposed integral wheels including,

a lower wheel, which meshes with the auxiliary wheel of the second rotating element, and

an upper wheel, which meshes with the meridian wheel of the moon bearing.

9. The timepiece mechanism according to claim **8**, wherein:

the auxiliary wheel of the second rotating element has 64 teeth,

the lower wheel of the moon wheel set has 43 teeth,

the upper wheel of the moon wheel set has 37 teeth, and

the meridian wheel of the moon bearing has 57 teeth.

10. The timepiece mechanism according to claim **1**, wherein the central wheel carries a crown toothing meshed with the moon pinion.

11. The timepiece mechanism according to claim **1**, wherein the central wheel is mounted for free rotation on the first rotating element.

12. The timepiece mechanism according to claim **1**, wherein the moon bearing is mounted for free rotation on the central wheel.

13. The timepiece mechanism according to claim **1**, wherein the moon bearing is fitted onto the central wheel with insertion of a smooth bearing.

14. The timepiece mechanism according to claim **1**, wherein the transmission wheel includes a pair of diametrically opposite jumper springs.

15. The timepiece mechanism according to claim **1**, wherein the star wheel has 29, 30 or 59 teeth.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 11,036,185 B2
APPLICATION NO. : 16/170228
DATED : June 15, 2021
INVENTOR(S) : Zaugg et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In Column 14, Claim 1, Line 21, delete “wheel)” and insert -- wheel --, therefor.

In Column 14, Claim 1, Line 38, delete “users;” and insert -- user; --, therefor.

Signed and Sealed this
Twenty-ninth Day of March, 2022

Drew Hirshfeld
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office